# Large Radiological Source Applications:

# RDD Implications and Proposed Alternative Technologies

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# Introduction

- Large Radiological Sources could be used to Produce Large and Dangerous RDDs
  - Radiological Sources are in Wide-Spread Use Around the World
  - The Radioactivity Range Spans Many Orders of Magnitude
- Attempts to Deny Access to Dangerous RDD Source Materials Must Focus on Larger Source Applications
  - The Potential Impact of RDDs Much Greater with Large Sources
  - There are Far Too Many Small Sources to Effectively Limit Access
- Improvements in Regulations and Source Security Can Make Illicit Acquisition More Difficult
- The Use of Alternate Technologies can Eliminate the Source Entirely, Make it Less Dangerous as an RDD Source, or Make it Much Tougher to Steal

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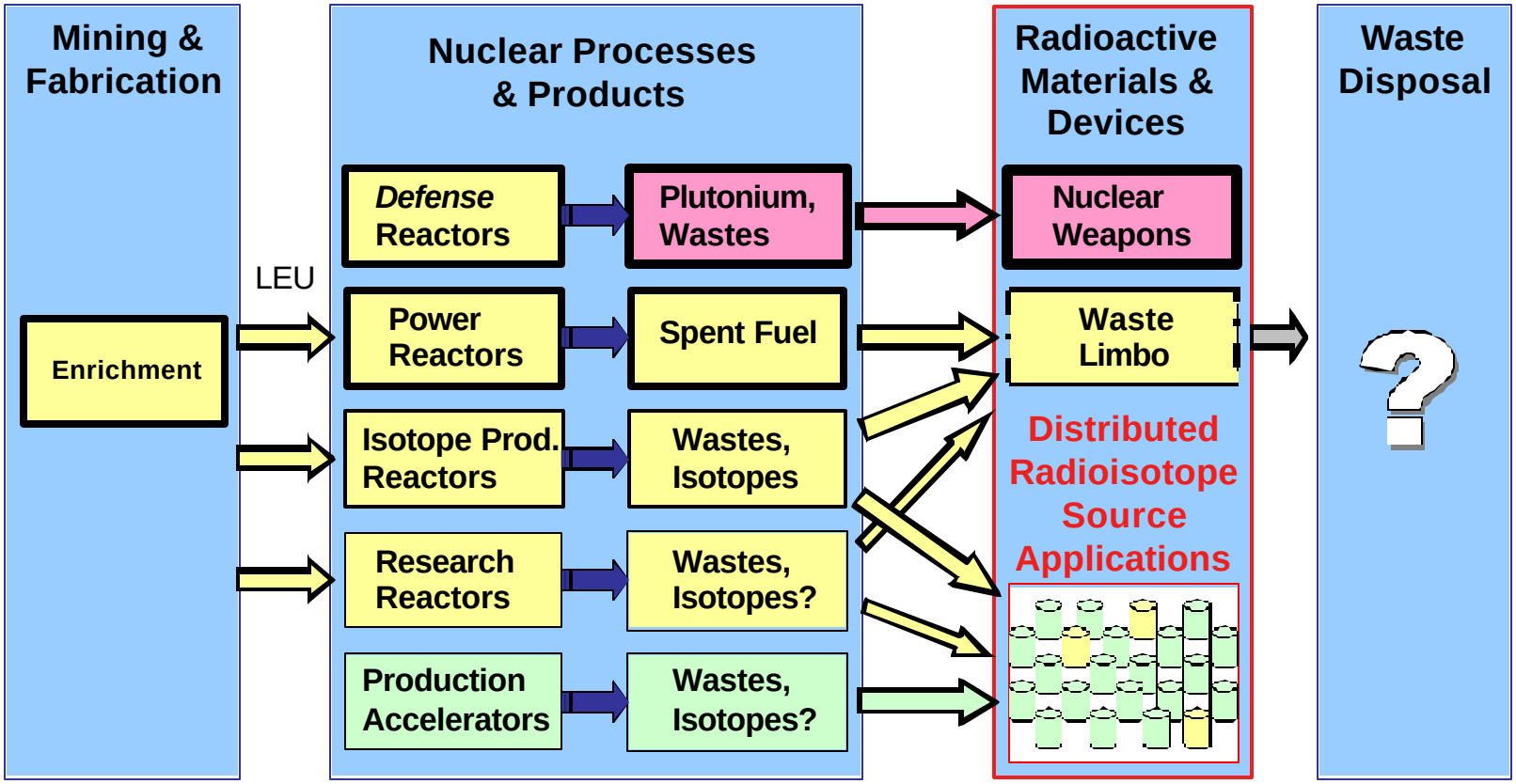
# Overview of Available Nuclear and Radiological Source Materials Production, Utilization, and Disposal Processes

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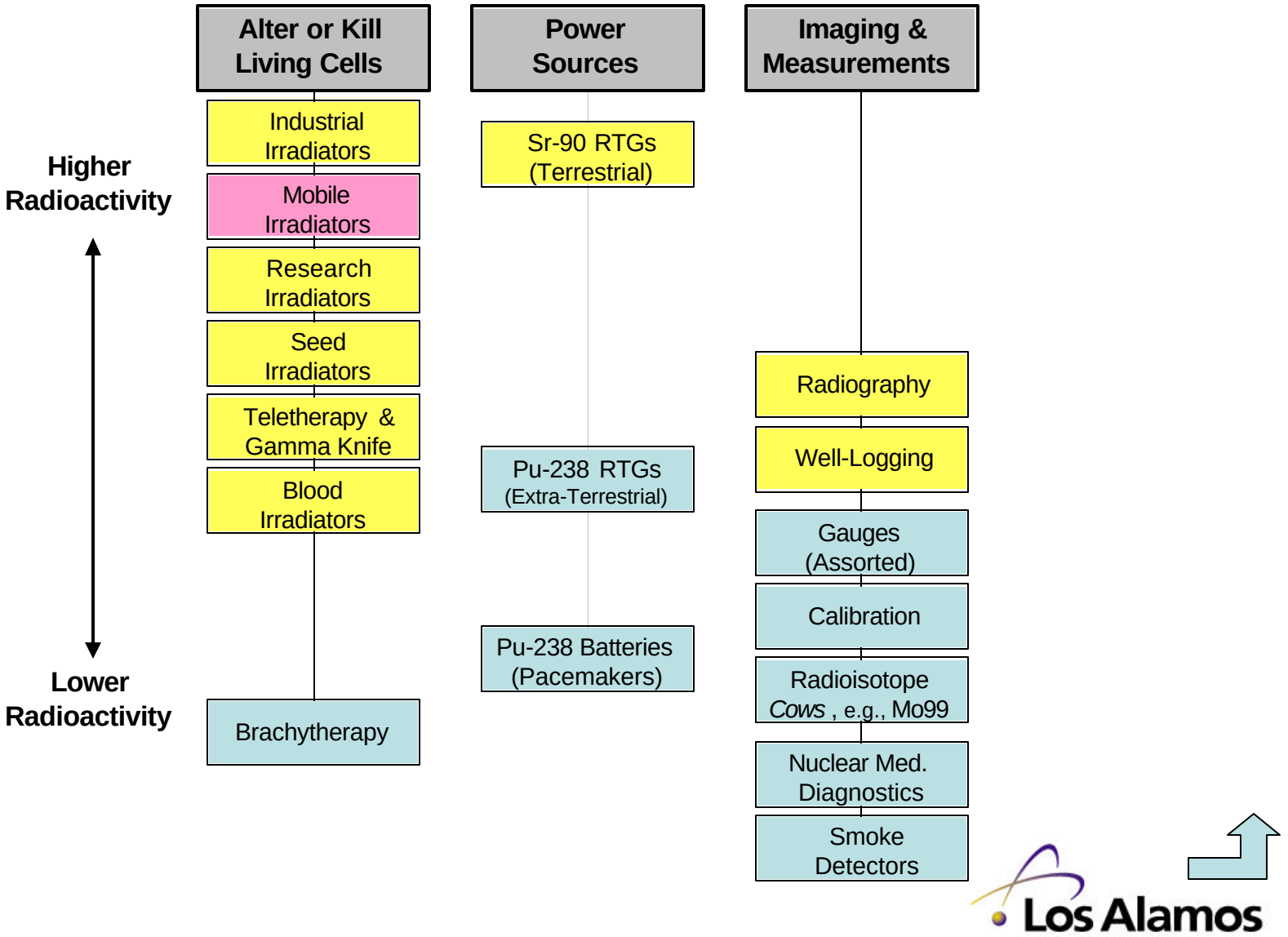
# Hierarchy of Radiological Source Applications

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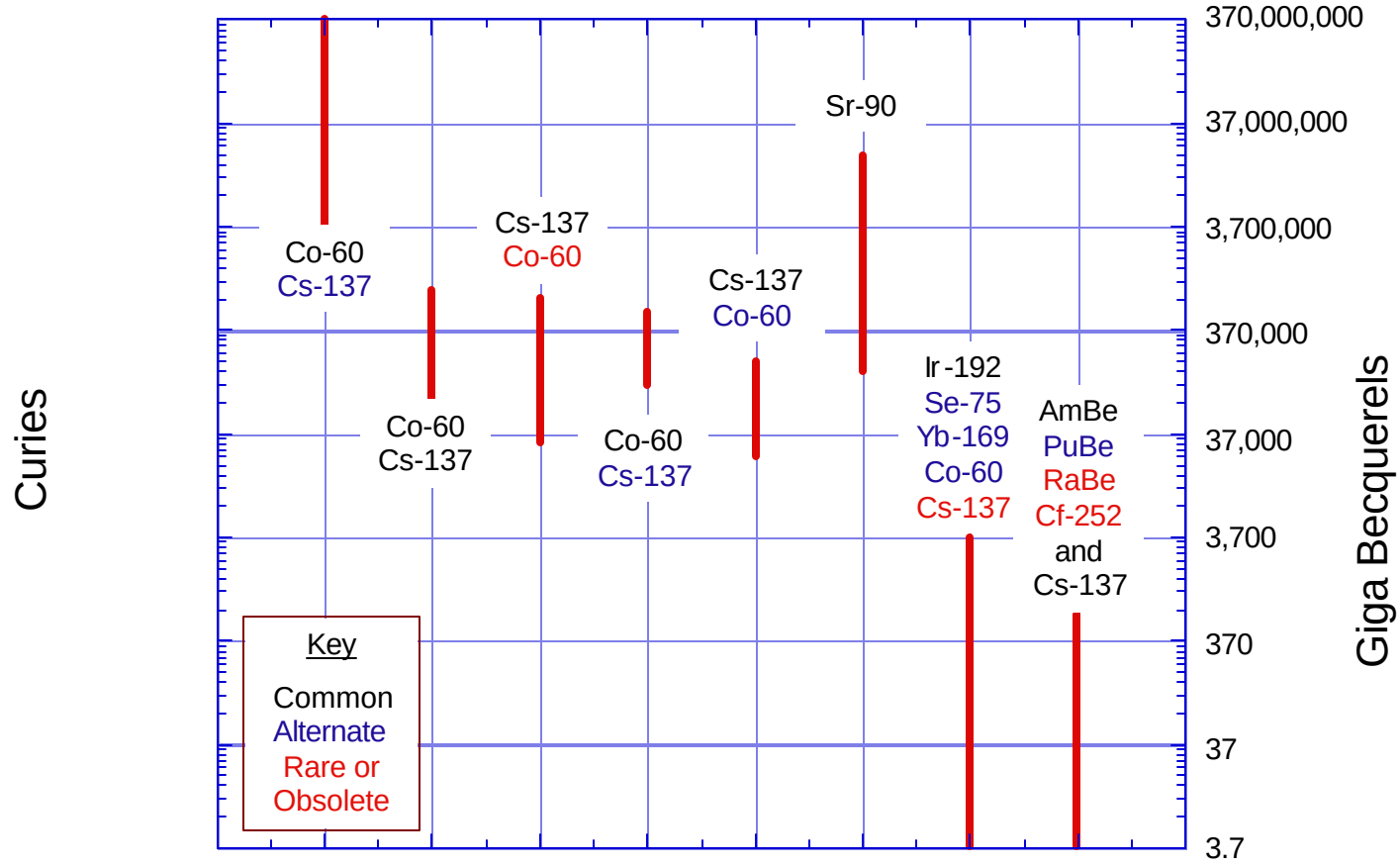
# Radioactivity Levels and Radioisotopes Utilized in Large Radiological Source Applications

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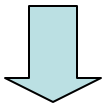
# Dose Relative to Cobalt-60 for Radioisotopes Used in Large Applications

| Isotope | Half-life | RHM Note 1 | CDE Ingest Note 2 | CDE Inhale Note 2 | RHM / RHM,Co | Ingest / Ingest,Co | Inhale / Inhale,Co |
|---|---|---|---|---|---|---|---|
| Co-60 | 5.3 yr | 1.37 | 26900 | 219000 | 1.0 | 1.0 | 1.0 |
| Cs-137 | 30.1 yr | 0.38 | 50000 | 31900 | 0.3 | 1.9 | 0.1 |
| Ir-192 | 74 d | 0.59 | 5740 | 28100 | 0.5 | 0.2 | 0.1 |
| Sr -90 | 29.1 yr | 0.00 | 142000 | 1300000 | 0.0 | 5.3 | 5.9 |
| Pu -238 | 88 yr | 0.08 | 3200000 | 392000000 | 0.1 | 119.0 | 1790.0 |
| Ra-226 | 1600 yr | 0.01 | 1320000 | 8580000 | 0.0 | 49.1 | 39.2 |
| Am-241 | 433 yr | 0.31 | 3640800 | 444000000 | 0.2 | 135.3 | 2027.4 |
| Cf -252 | 2.6 yr | 0.04 | 1084100 | 136900000 | 0.0 | 40.3 | 625.1 |

Note 1: Rem per hour at 1 meter per curie  Note 2: 50 year cumulative dose, per curie

Source: Handbook of Health Physics & Radiological Health by Shleien



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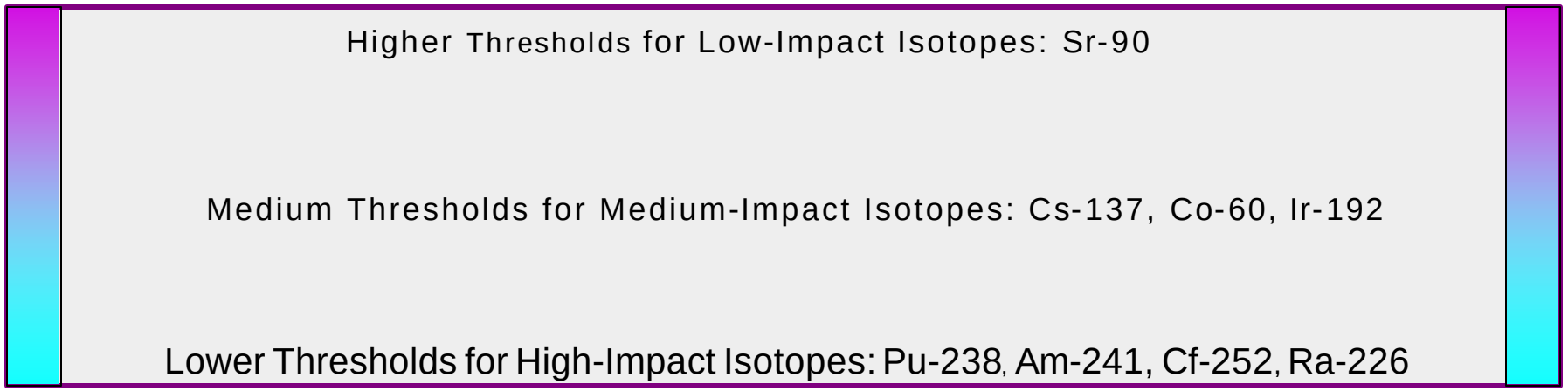
# A Thresholds Bar can be used to Differentiate Amongst the RDD Dangers Posed by Different Radioisotopes




A Thresholds Bar can be used to compensate for differing levels of concern regarding radioactivity levels of the different radioisotopes. A simple thresholds bar, based on likely dose impacts is shown above. More sensitive versions could include data on potential dispersion, detection, and decontamination issues

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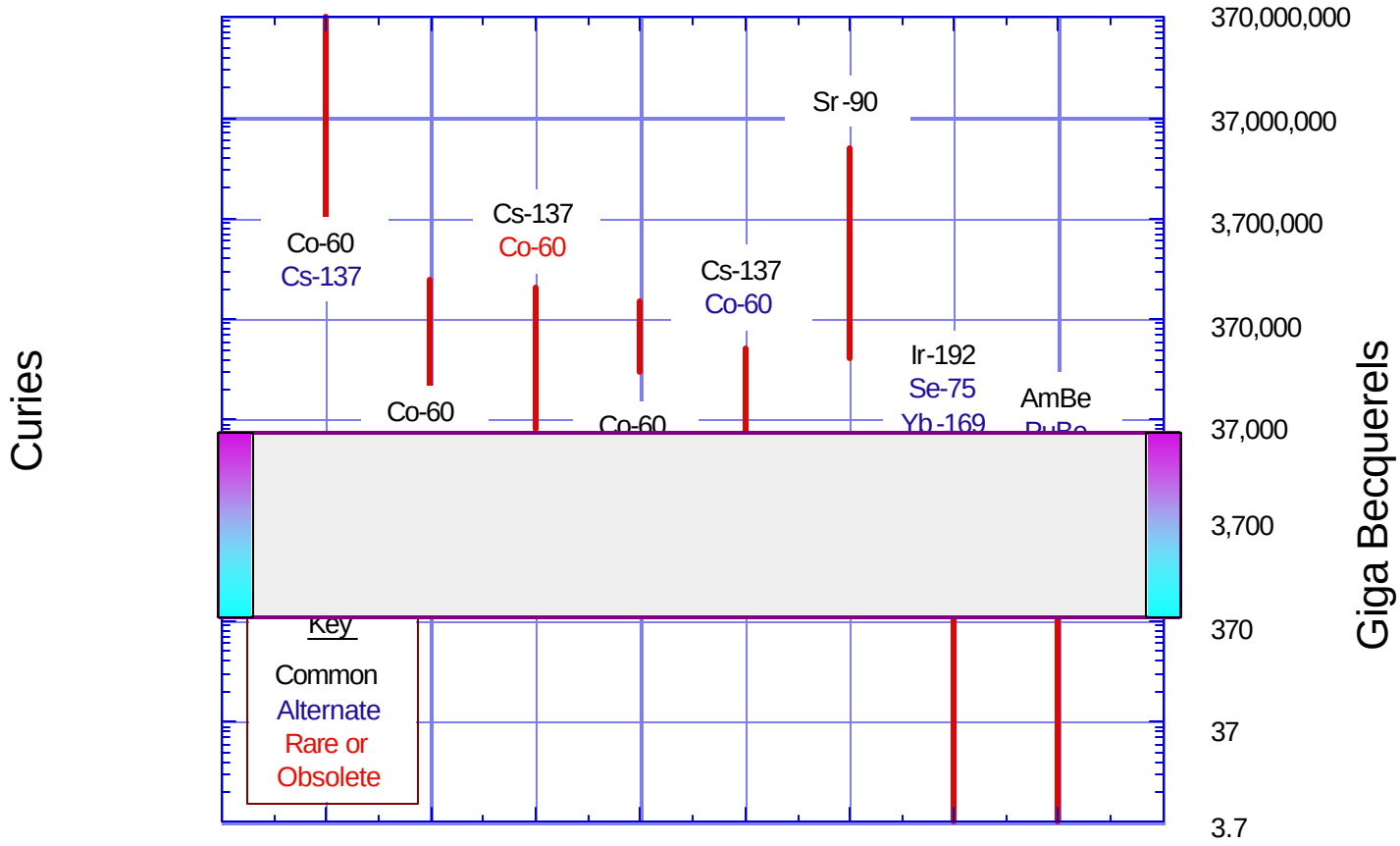
# Most Large Applications Exceed the Thresholds of Concern

## Some Radiography & Well-Logging Source Exceed the Thresholds

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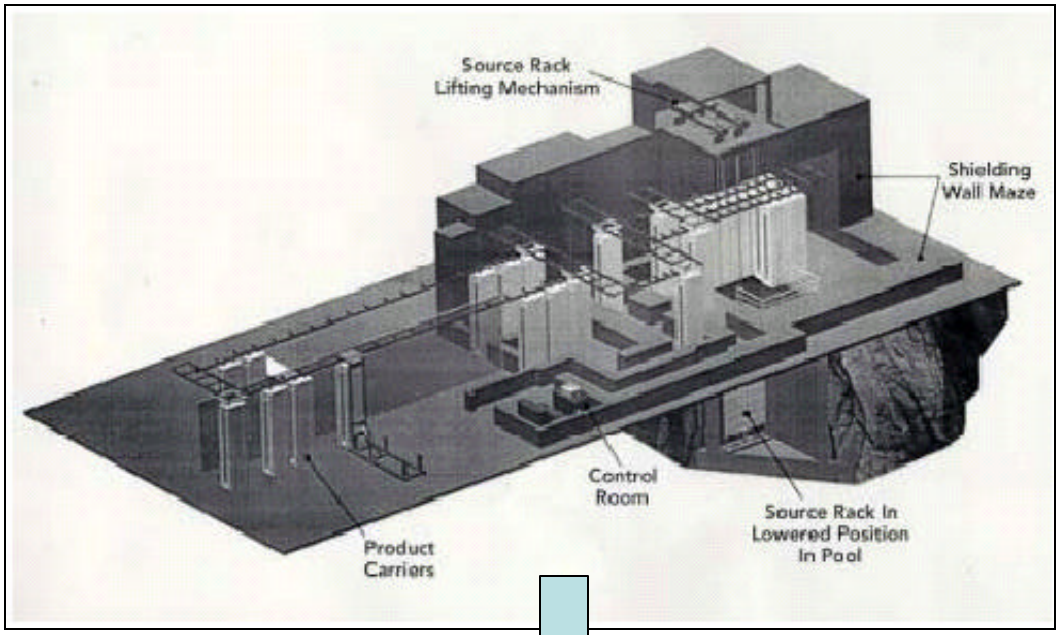
# Industrial Irradiators Use Millions of Curies of Co-60

- We have identified 191 Units World-Wide
  - Sterilize Medical Instruments, Irradiate Food, etc.
  - Security Systems Significant; Self-Protection *Formidable*
  - Sources Must be Reloaded Often (5.27 Year Half-Life)
- Concerns:
  - Enormous Quantity of Dangerous RDD Source Material
  - Frequent Re-Supply Raises Concerns About Theft

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# Research Irradiators Use Large Amounts of Cesium

- Smaller than Industrial Irradiators, they are used for Similar Purposes, in Addition to Research
  - They typically use 10,000 to 20,000 Curies of Cesium-137 (less shielding than cobalt-60)
  - There may be ~100 to 200 Units World-Wide
  - They are Usually Located in Research Environs
- Concerns
  - Much More Vulnerable Than Industrial Irradiators
  - Cesium-Chloride Source Material Behaves Badly When Accidentally Dispersed

**Research Irradiator from Nordion**

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## Mobile Irradiators are Uncommon but Could Become Concern

- Large Cesium Sources Could be Transported Regionally/Seasonally for Food Irradiation
  - Designs Have Been Featured/Marketed on Web Sites
  - Regulatory Concerns May Be Slowing Deployment, e.g., U.S
  - Recent USDA Approval for Importing Irradiated Produce Could Accelerate Deployment of Technology Outside U.S.
- Concerns
  - Very Large Amount of Cesium
  - Trucks Could be Vulnerable to Theft

**A Large Mobile Irradiator (250,000 Curies of Cesium) is described on a Beijing Institute of Nuclear Engineering Web Site .**


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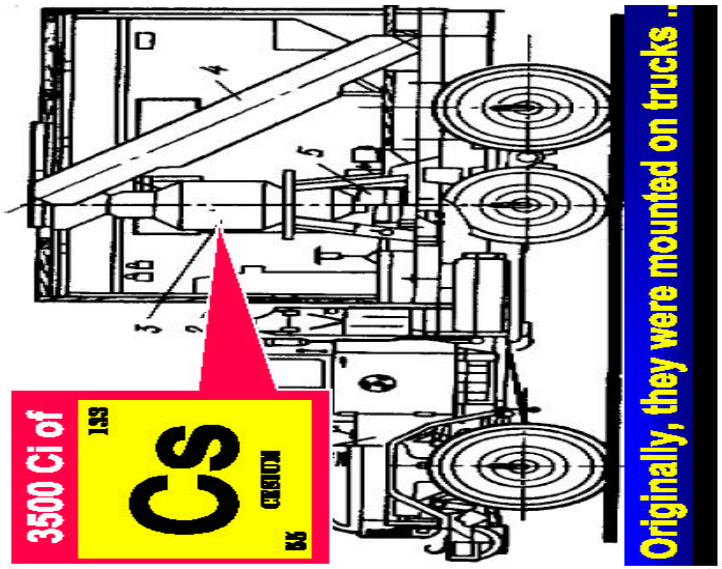
## Seed Irradiators are Large Orphans from a Former Soviet Program

- Agricultural Testing Program: Impact of Radiation on Seeds
  - Each Units Used about 3,500 Curies of Cesium Chloride
  - Tests Conducted in Several Regions around FSU
  - Probably Hundreds of Units Used During 1970s & early 1980s
  - Orphans Turn Up in Groups of 3 or 4 in Open Storage Areas
- Concerns
  - Very Large Orphans Stored in Open; Obvious & Vulnerable

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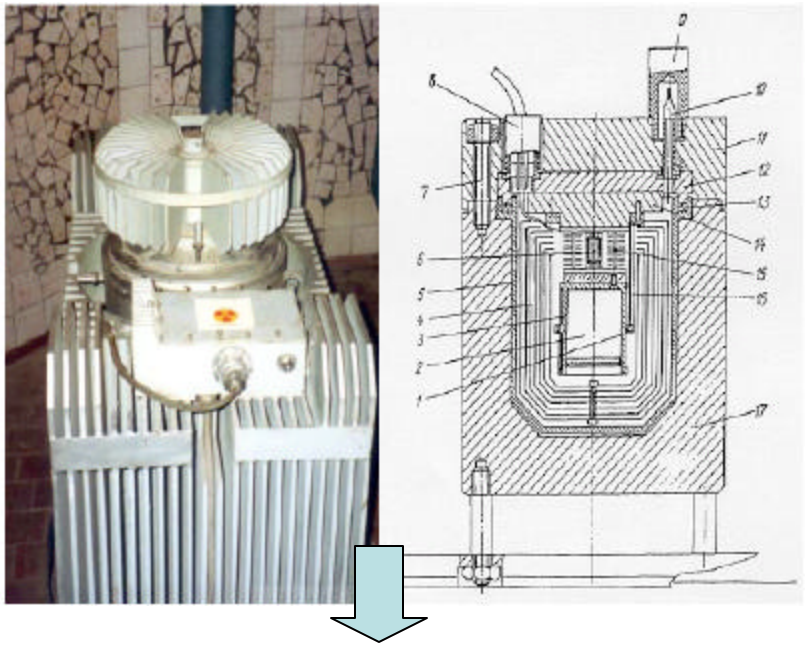
## Radioisotope Thermoelectric Generators (RTGs) (Terrestrial)

- Large Amounts of Strontium-90 Used for Remote Power Source
  - 5,000 to 500,000 Curies of Sr-90
  - Used in Remote Locations, e.g., North Coast of Russia
  - Many Disused and Orphan Sources, mostly around FSU
- Concerns:
  - Remote Usage Causes Concerns About Theft
  - Disuse/Orphan Status of Many RTGs Heightens Concerns

Soviet Design RTGs are Usually Called RITEGs, and Sometimes *Lighthouses (a common application)*



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## Teletherapy Units are Used Around the World to Treat Cancer

- Teletherapy Typically Uses about 5,000 Curies of Cobalt-60
  - Initially Used Cesium-137 and Common in the U.S.
  - When U.S. Hospitals Switched to Accelerator, Teletherapy Exported
  - IAEA Programs Also Provided Teletherapy to Third World
  - Thousands of Teletherapy Devices in Use; Nearly All Using Co-60
- Concerns
  - Hospitals Rarely Feature Much Security
  - Frequent Shipments of Cobalt Could Also be Targeted for Theft

*Medical Teletherapy Unit, Vietnam*

*Medical Teletherapy Unit Typical of Those Used in Central and Eastern Europe*

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## Blood Irradiators are Used to Sterilize Blood Before Transfusions

- Used Primarily in U.S. and Western Hospitals
  - From 600 to 5,000 Curies of Cesium-Chloride Welded into Unit
  - Large and Heavy- Like Big File Cabinet
  - Prevents Graft-Versus-Host Disease (GVHD) in Weakened Patients, e.g., in Cancer Wards
- Concerns
  - Large Quantities of Cesium Chloride in Low Security Environment
  - Export of Technology Overseas May Increase

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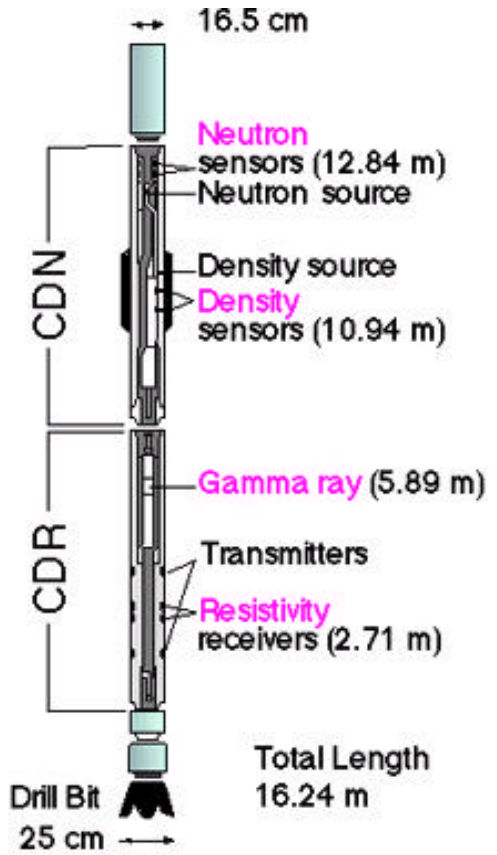
# Well-Logging Sources are Used in the Global Search for Oil

- Well-Logging Sources include Neutrons and Gammas to Survey the Geology Adjacent to Exploratory Bore-holes
  - Neutron Sources in 10-20 Curie Range (AmBe)
  - Gamma Sources ~30 Curies (Cesium-137)
  - Three Multi-National Companies Dominate Field, Taking Sources from Country to Country and Site to Site
- Concerns:
  - Alpha Emitters, such as Am-241, Could be Nasty RDD Sources
  - Well-Logging Sources are Portable, and there are Opportunities for Theft
  - AmBe Sources are in Packed-Powder Form to Increase Neutron Efficiency

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## Alternate Technology Options can be Grouped into 4 Categories

- Replace the technology entirely using a device that performs the same function without using a large radiological source or by eliminating the need for such a device
- Replace a problematic radioisotope using one that poses less risk if used in an RDD
- Improve upon the radiological source chemical or mechanical form so as to make it more dispersion resistant
- Develop and deploy technologies within the radiological source application to make it more difficult to steal and/or to make it easier to recover the source if stolen

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## Options for Replacing Problem Source Applications

- Replace the technology using one that provides an equivalent capability
  - Particle Accelerators can provide large amounts of radiation, including a range of particle types and energies
  - X-Ray devices (mini-accelerators) can be substituted for blood irradiators; other substitutions should be possible soon
  - For some applications in some locations, solar or wind power may be substituted for RTGs
  - For some well-logging applications, D-T sources can be used to replace the AmBe neutron sources
- Eliminate the need for the source application
  - Many of the RTGs are used to power lighthouses along the North coast of Russia. If the lighthouses were to be replaced using GPS systems or other modern technologies, RTGs would not be needed

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## Options for Replacing Radioisotopes

- Some radioisotopes can contribute to the severity of an RDD attack and may be candidates for replacement
  - The alpha-emitting Am-241 could be replaced by a short-lived gamma emitter if a monoenergetic neutron source below 1 MeV would suffice (unlikely)
  - If an alternate chemical form of cesium does not prove to be practical, the cesium-137 could be replaced by a similar gamma-emitter
- Some radioisotopes are more likely to be used as RDD sources because of their half-lives
  - The Am-241 half-life of 433 years means the source outlives the application. Isotopes of Polonium or Curium could be used instead
  - Radiography sources should be short-lived, so any cesium-137 sources should be replaced
  - The 5.27 year half-life of cobalt requires frequent shipments of new sources to irradiators and teletherapy units, making transportation a potential concern (for theft)

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## Alternate Chemical (or Mechanical) Forms could Resist Dispersion

- The Accidental Dispersion of a Cesium-Chloride Teletherapy Source in Goiania, Brazil Indicates this Material could Perform Poorly During Some Types of RDD Scenarios
  - Cesium tetraflourborate may be a viable alternative to cesium chloride
  - If heated to 700 degrees, CsCl turns to glass. In glass form the material would not disperse as easily
- The AmBe Sources are composites of americium oxide and beryllium. Where these sources are compressed powders (two interspersed powders), alternate forms should be developed
- Strontium chloride has been used in the past and can still be obtained. Strontium titanate is a preferred form.

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## Source Application can be Modified to Make Theft more Difficult

- Sensors and Transmitters can sound Alarms
  - Large sources should transmit “All-is-clear” signals when operating normally and alarm in response to changes
    - Industrial irradiators should alarm on unexpected decreases in source strength
    - RTGs should alarm on several types of perturbations
  - Trucks transporting large source materials or mobile irradiators should be tracked vs. pre-planned routing and alarm if diverted
- Tracking technologies used to find stolen cars can be used for some large sources
  - The cesium sources in blood irradiators are welded in, so the large and heavy unit will likely be stolen and transported
  - RTGs, Well-logging source *sondes*, and other sufficiently large applications should be so-equipped

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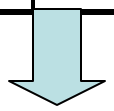
| Class of Source Application: | Application | Competing Technology | Alternate Radioisotopes | Alternate Chemical Form | Modify Application |
|---|---|---|---|---|---|
| **Industrial Irradiators** | **Industrial Cobalt Units** | ***Particle Accelerators*** x-rays (future) | - | - | ***Alarm on low source strength, MPC&A*** |
| **Research Irradiators** | **Research, Smaller Scale Irradiator** | ***Accelerators***, Industrial units x-rays (future) | If Cesium, replace with Co-60 or other | ***Replace CsCl*** | Secure and Alarm Facility, MPC&A |
| **Large Medical** | **Teletherapy** | Particle Accelerators | ***If Cesium, replace with Cobalt*** | ***If CsCl, replace*** | ***Secure source in unit, MPC&A*** |
| **Large Medical** | **Blood Irradiators** | ***x-ray units*** | Replace Cesium | ***If CsCl, replace*** | Alarm & track if stolen, MPC&A |
| **Power Source** | **SR-90 RTGs** | *Solar, Wind;* ***GPS Systems*** | | | Alert & track if stolen |
| **Mobile Scanning** | **Well-Logging: Neutrons** | ***D-T neutron generators*** | Replace Am-241 with Po or Cm isotopes | ***Modify AmBe Form*** | Rig for Alert & track if lost or stolen |
| **Mobile Scanning** | **Well-logging: gammas** | - | Replace cesium? | ***If cesium, use ceramic*** | Rig for Alert & Track if Lost or stolen… |
| **Mobile Scanning** | **Radiography** | - | Iridium preferred | ***If cesium, use ceramic*** | Rig larger units for alert & track |



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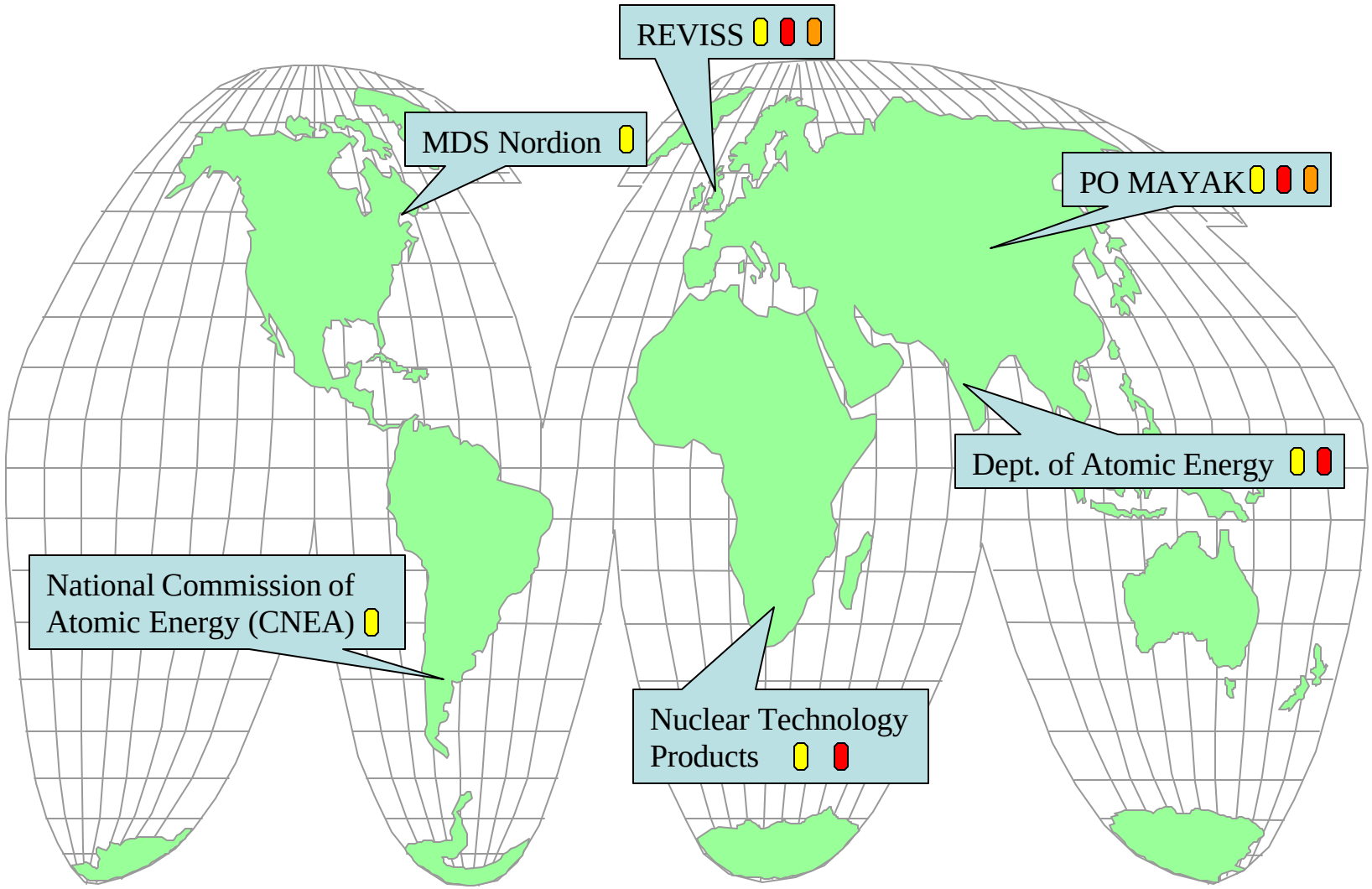
# Major Radioisotope Producers




**Cobalt 60 Production** **Cesium 137 Production** **Strontium 90 Production**

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# Recommendations

- The RDD Risks due to Large Radiological Source Applications can be Reduced through the Use of Alternate Technologies
  - Problem applications, such as RTGs, could be eliminated
  - Problem materials, such as cesium-chloride, could be banned
- The Substitution of Alternate Technologies would Require International Cooperation, especially among the Source Manufacturers and Suppliers
  - Preliminary discussions indicate this community may be willing/ eager to cooperate
  - Technology developments may require augmentation by U.S. laboratories
- Substitution of Alternate Technologies may not progress quickly, but the changes could have lasting impacts on RDD Risks

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